Memorandum

To: Lisa Tobin

From: Susan Fenhaus

Date: January 8, 2019

Re: Well 4 Power and Chlorination Improvements Project C512A

Statement of Problem to be Resolved

The emergency generator that was installed as part of Project C512A is not able to start Well 4 automatically upon loss of utility power, and must be manually started by adjusting the settings on the well's soft starter controls beyond the manufacturer's recommendations. Water Operations seeks to resolve this situation so that the generator can perform automatically during power emergencies, freeing staff for other emergency tasks. Well 4 emergency generator needs to be able to start the motor at its normal operating set point in order to not cause possible damage to the well motor. The soft starter currently needs to start the motor at 30% power in order for the generator to be able to handle the draw. Starting the motor at this set point makes the motor start slower which in turn creates excessive heat, therefore damaging the motor components. The generator and wiring need to be upsized in order to be able to handle the motors power needs, and therefore be able to be utilized in a fully automatic process.

Description of Project C512A

This 2012-2015 project provided a 450 kW diesel-fueled generator and new hypochlorite disinfection equipment in a new building at the Well 4 site. The objectives were:

1. To upgrade the chlorination system by replacing gas chlorine with liquid sodium hypochlorite. Upgrades were designed to improve operator safety, reduce City liability, and improve maintenance and operations.
2. To provide emergency power to ensure one of the City's primary sources of water will continue to operate in the event electrical power from the grid is lost.

Start-up of the new facilities occurred in June 2016. The project did not perform as expected. The chlorination system improvements operated as planned; however, the generator did not start the 350 HP well motor. The generator could not produce the large initial power demand needed to start the motor. Full speed motor operation uses less current than at start up. Adjustments were made to the existing soft starter to allow the motor to start slower. The generator was then able to start the well pump. The pump and motor contractor cautioned that this modification could cause the motor to overheat because of the slower start.

Chronology of Events after Start-up

- December 13, 2016 meeting with project design consultant RH2. RH2 provided information that generator was sized correctly, that the existing soft start is too sensitive to voltage reductions, and suggested either an uninterruptible power supply on the soft starter control or replacing the soft start with a variable frequency drive (VFD) to improve operation. See meeting summary attached to this memo.
- The City felt a new VFD was the best option and hired Parametrix to perform the work.
- Parametrix reviewed RH2 information and existing soft starter documents. They felt replacing the soft starter instead of a VFD with a new soft starter model that had better programming capabilities and the ability to handle very low voltage drops was a better option.
- August 2017 - A new soft starter was installed, set to ramp up slow enough for generator to start motor.
- April/May 2019 - The motor overheated. Motor was pulled, rebuilt and re-installed.
- June 2019 - The new soft starter was re-programmed by Parametrix to ramp up quicker. The generator will not start the motor this way. In the event of a power outage, M&O can manually adjust setting of soft starter to allow generator to start motor. This removes the automatic operation of the generator, but still allows the well to be utilized if power is lost to the station.
- July 2019 - The well failed to operate when called for. It may have been due to the soft starter not being allowed to self-program after initial installation, but this theory has not been tested. The pump and motor were not damaged, and are good. The new soft starter installed in 2017 was pulled. It was replaced with re-built soft starter with 1 year warranty.
- August 2019 - The soft starter was re-installed and the well has been running as needed under normal utility power. It has not been tested under emergency power either by manually disconnecting the utility power or due to an unanticipated outage.

Options and Recommendations:

After making improvements and adjustments to the new equipment, we determined we have two options:

1. Do nothing. The generator will run the well pump; however, this is a manual procedure. If power is lost to the station, an operator will have to go to the site and change the settings on the soft starter before the generator will start the well. This would delay operation of the well, especially when it is critical to utilize the water source.

2. Replace the generator. The original design consultant's calculations show the generator is sized for the pump motor power requirements once the pump is running ("normal operations"), not for the larger power load required at startup.. Our experience indicates the generator is undersized and not capable of starting the motor unless adjustments are made to the soft starter. A larger generator would enable automatic operation of the generator in the event of power loss to the station. This would save time in an emergency and allow the operators to focus their attention on other priorities. The original design consultant's claim that the generator should not be oversized because it could suffer from "wet-stacking" (buildup of fuel in the exhaust and turbocharger that could lead to premature failure) should be evaluated.

The recommended action is Option 2 - Replace the Generator. Include analysis of the entire facility to determine if other components also need replacing, such as the wire from the generator to the motor control center and verification that the existing soft starter is functioning properly under both utility and emergency power. The existing generator may be used at a different site that does not currently have emergency power, such as the Lea Hill Booster Pump Station which has smaller pumps. We recommend that knowledgeable and independent consultant evaluate the situation rather than using the previous consultants.

City of Auburn

Auburn Well No. 4 Standby Generator

MEETING AGENDA

Date: **December 13, 2016**

Time: **2:00 P.M.**

Introductions

Project Startup

- Soft Starter was stuttering during pump motor starting.
- No generator faults or overcurrent protection alarms were observed.
- Soft Starter Tuning
  - Motor Current Limit was reduced from 380% of the motors full load amps to 325%.
- It was demonstrated that the pump motor operated successfully on both Utility and Generator power

Generator Sizing

- Steady State Load (Running load)
  - It is critical that a generator is not grossly oversized for a facility; oversizing the generator can result in poor diesel engine performance and cause issues such as wet-stacking (buildup of fuel in the exhaust and turbocharger) that can lead to premature failure. It is recommended that a facility's running load be at least 50% of the generators rating to ensure the generator is being exercised properly.
- Motor Starting Load
  - As motors start they draw much more current than they do at full speed. The purpose of a soft-starter or variable frequency drive (VFD) is to limit this current so that power supplies (transformers, generators) can be provided without excessive oversizing.
- Voltage Dip. As the motor starts it draws a large amount of current, which causes voltage of the facility to drop, or dip, temporarily.
  - The industry standard is to allow up to a 35% voltage dip. (See *Attachment 3*)
  - The current EG at Well No. 4 is designed to allow only a 19% voltage dip during starting. (See *Attachment 2*). During the initial site visit it was

confirmed that the measured voltage dip during motor starting was 19.1%. (See *Attachment 1*).

- Prior to RH2 involvement the City had Cummins evaluate the facility and recommend an adequate generator size. Cummins responded that a 350 kW generator with a NEMA type 1 automatic transfer switch would be sufficient to serve the station.

Current Issues

- The Soft Starter is experiencing a "Motor thermal overload during acceleration/start mode"
    - Per the Soft Starter Manufacturer's literature this is due to an excessive load on the motor, inadequate acceleration settings or high friction starting conditions.
- No generator faults or overcurrent protection alarms were observed.

Potential Causes

- Based on the information provided to RH2 it appears that the generator is not at fault, but that the Soft Start is very sensitive to facility voltage. In discussions with the Soft Start manufacturer they stated that their equipment cannot tolerate more than a 10% voltage dip, despite this not being identified on any of their product literature. No major generator manufacturer can provide a generator that meets these requirements.
- Degrading Equipment or Changing Conditions- the equipment was functional as of June 2016. Potential causes could consist of:
    - Motor insulation degradation
    - Motor bearing wear
    - Pump bearing wear
    - Pump wear
    - Changing hydraulic conditions

Potential Solutions

- Additional Soft-Starter Tuning
    - Increasing the Motor Current Limit in 10% steps could find a compromise between 325% (current setting) and 380% (previous setting) that would allow the motor to start on either power source
- Installation of an uninterruptable power supply (UPS) on the Soft Starter control circuit. $800 installed
- Replacement of the Soft-Starter with a Variable Frequency Drive (VFD).

≈ $15,000 Purchase + Install VFD
SCADA program fairly simple to modify

Attachment 1 – Field Recorded Data

Table 1: Pump Motor Electrical Transient Data

Test	Power Source	Maximum Current Limit	Acceleraton Ramp Time (seconds)	Measured Voltage Dip	Measured Starting Current (Amps)
1	Utility	380%	4	11.5%	1359
2	Utility	350%	1	11.9%	1508
3	Utility	325%	4	8.6%	1202
4	Generator	325%	4	19.1%	1206
5	Generator	325%	4	19.2%	1192

Figure 1 demonstrates the current (amperage) waveform measured during Test 1; on utility power with the baseline settings of the soft-start.

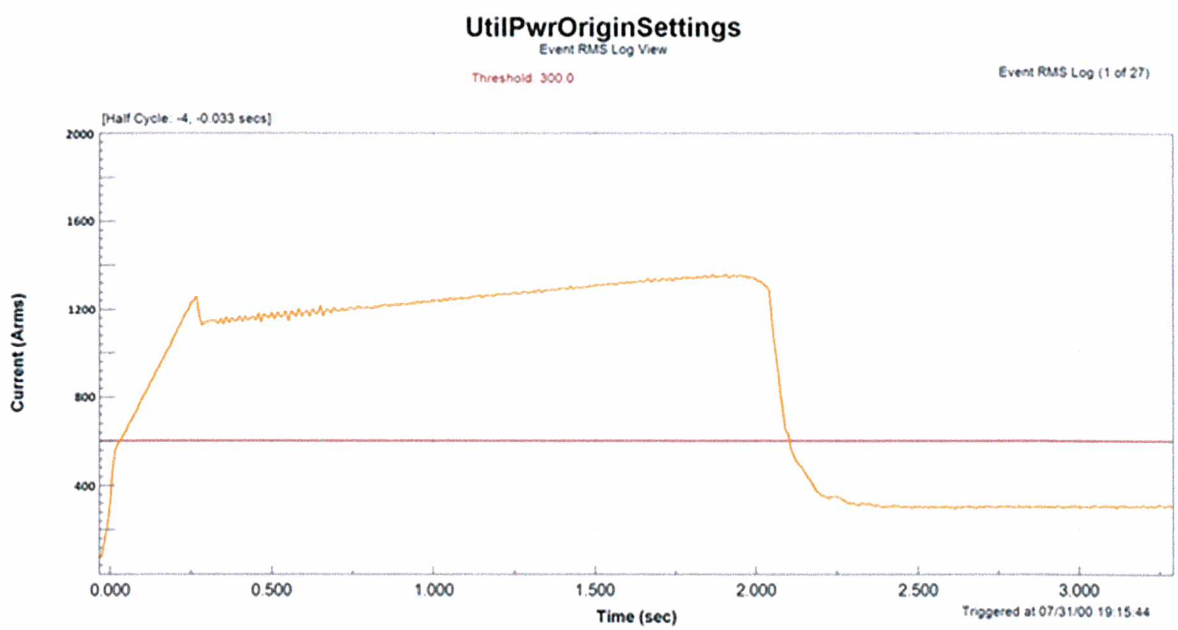


Figure 2 demonstrates the voltage waveform measured during Test 1; on utility power with the baseline settings of the soft-start.

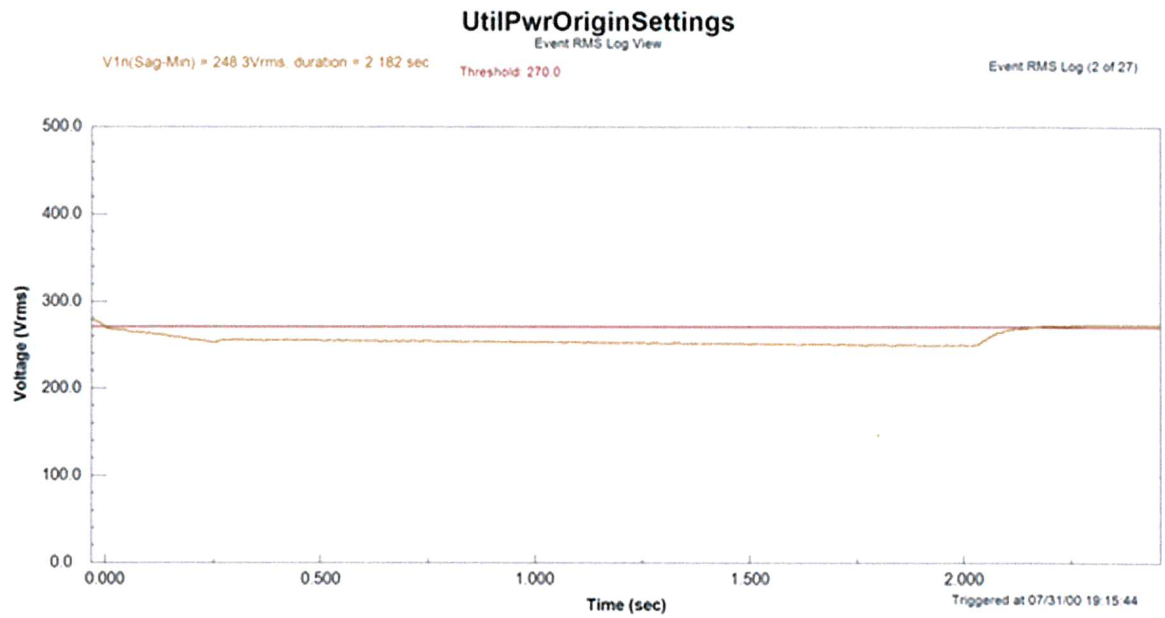


Figure 3 demonstrates the current (amperage) waveform measured during Test 3; on utility power with the optimized settings of the soft-start.

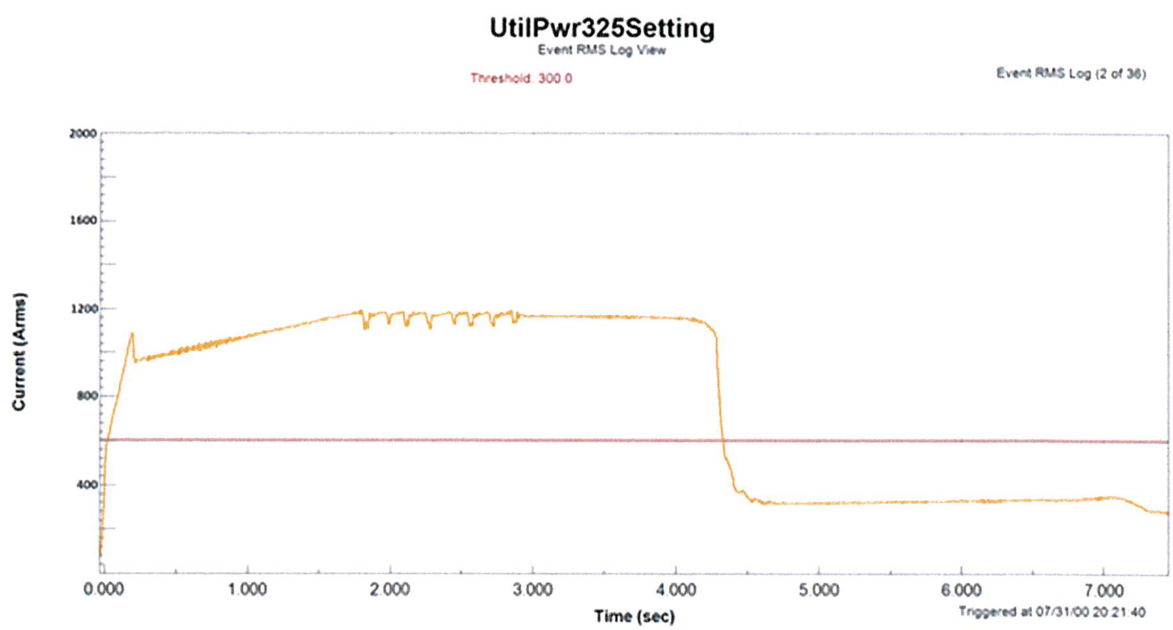


Figure 4 demonstrates the voltage waveform measured during Test 3; on utility power with the optimized settings of the soft-start.

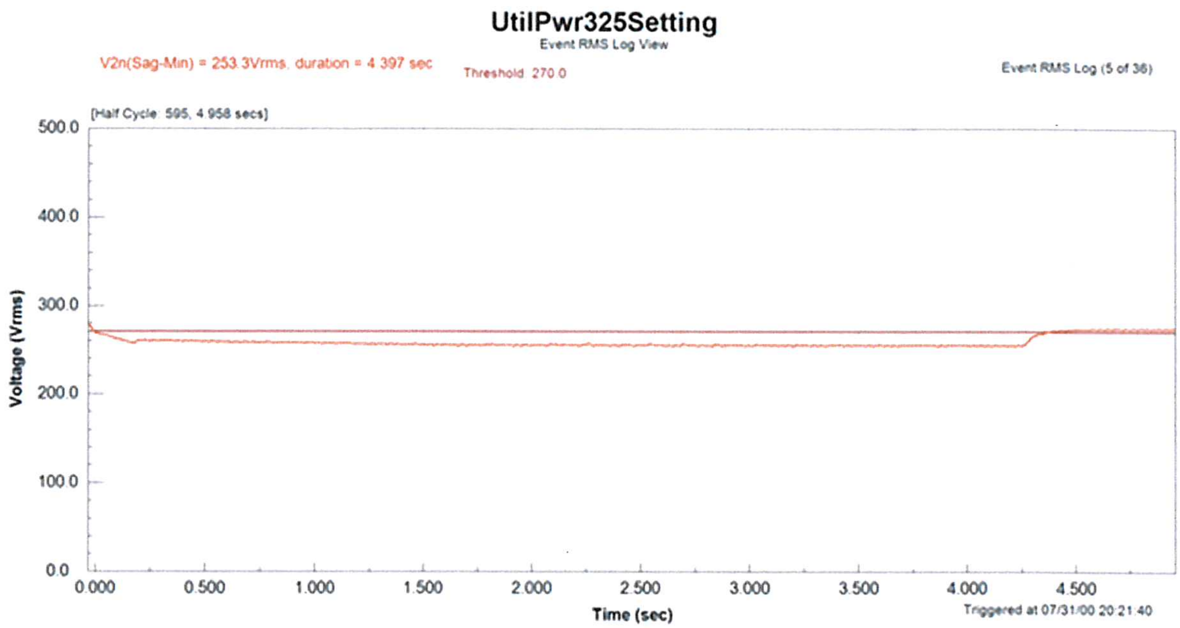


Figure 5 demonstrates the current (amperage) waveform measuring during Test 4; on generator power.

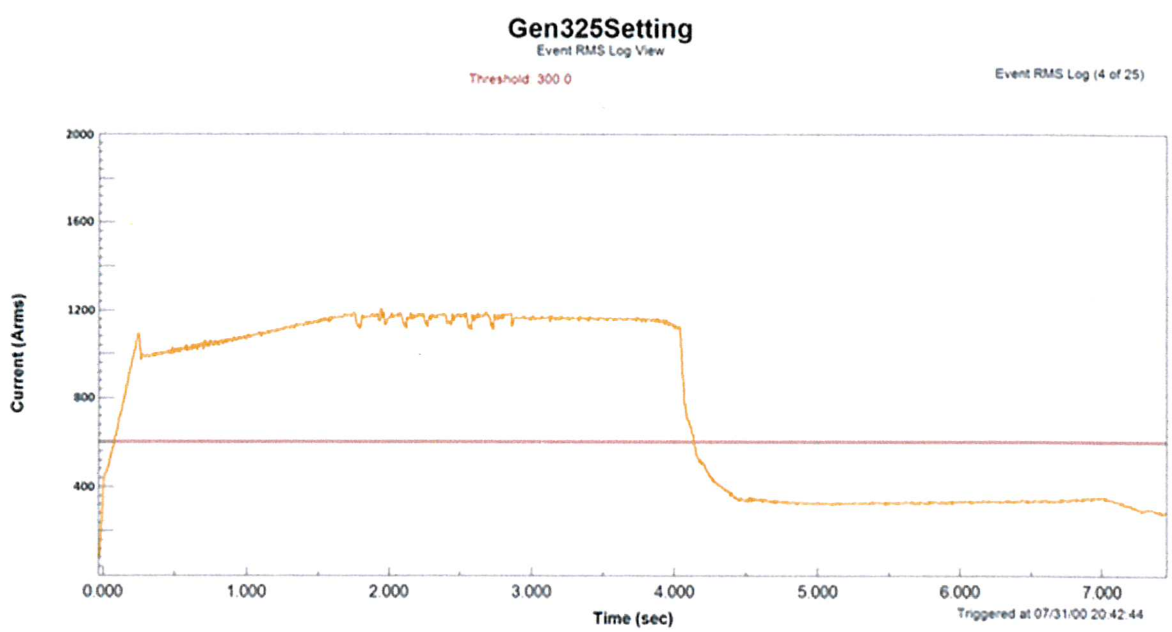
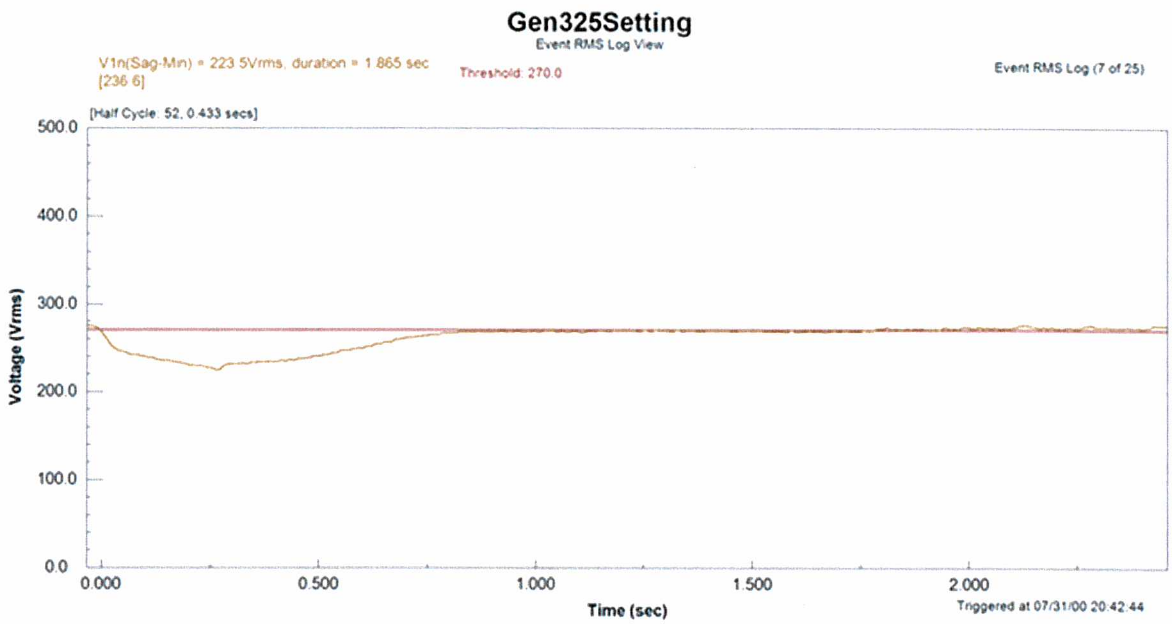


Figure 6 demonstrates the voltage waveform measured during Test 4; on generator power.



Attachment 2 – Generator Sizing Information (19% Voltage Dip)

Power Generation

Recommended Generator Report - 450DFEJ*

Project - Auburn Well_4

Comments - Based on field notes during startup.

Project Requirements

Frequency, Hz	: 60.0	**Generators Running in Parallel**	: 1
Duty	: Standby	**Site Altitude, ft(m)**	: 361(152)
Voltage	: 277/480, Series Wye	**Site Temperature, °C**	: 25
Phase	: 3	**Max. Altr Temp Rise, °C**	: 125
Fuel	: Diesel	**Project Voltage Distortion Limit, %**	: 10
Emissions	: EPA, stationary emergency application		

Calculated Individual Generator Set Load Running and Peak Requirements

Running kW	: 264.4	**Max. Step kW**	: 243.1 In Step 2	**Cumulative Step kW**	: 272.0
Running kVA	: 326.9	**Max. Step kVA**	: 1105.2 In Step 2	**Cumulative Step kVA**	: 1141.2
Running PF	: 0.81	**Peak kW**	: None	**Cumulative Peak kW**	: None
Running NLL kVA	: 0.0	**Peak kVA**	: None	**Cumulative Peak kVA**	: None
Alternator kW	: 264.42			**Pct Rated Capacity**	: 58.7

Generator Set Configuration

Alternator	: HC5E	**Engine**	: QSX15-G9 Nonroad 2
BCode	: B258	**Fuel**	: Diesel
Excitation	: PMG	**Displacement, cu in. (Litre)**	: 912.0(14.9)
Voltage Range	: ER 190-240/380-480	**Cylinders**	: 6
Number of Leads	: 12	**Altitude Knee, ft(m)**	: 7215(2199)
Reconnectable	: Yes	**Altitude Slope, % per 1000ft(304.8m)**	: 6
Full Single Phase Output	: No	**Temperature Knee, °F(°C)**	: 104(40)
Increased Motor Starting	: No	**Temperature Slope, % per 10°F(5.56°C)**	: 6
Extended Stack	: No	**Emissions**	: EPA Tier 2
		Cooling Package	: high ambient

Set Performance / Load Requirements

Set Performance		Load Requirements	
Running At	: 58.7% Rated Capacity		
Max. Step Voltage Dip, %	: 19	**Max. Allowed Step Voltage Dip**	: 20 In Step 2
Max. Step Frequency Dip, %	: 4	**Max. Allowed Step Frequency Dip**	: 10 In Step 2
Peak Voltage Dip, %	:	**Peak Voltage Dip Limit %**	: 20.0
Peak Frequency Dip, %	:	**Peak Frequency Dip Limit %**	: 10
Site Rated Standby kW/kVA	: 450 / 563	**Running kW**	: 264.4
		Running kVA	: 326.9
Site Rated Max. SkW	: 518	**Effective Step kW**	: 268.7
Max. SkVA	: 1766	**Effective Step kVA**	: 1062.0
Temp Rise at Full Load, °C	: 125	**Percent Non-Linear Load**	: 0.0
Voltage Distortion	:	**Voltage Distortion Limit**	: 10
Site Rated Max Step kW Limit	:	**Max Step kW**	:

*Note: Higher temperature rise at full rated load.

*Note: All generator set power derates are based on open generator sets.

Power Generation

Steps and Dips Details Report

Project - Auburn Well_4

Project Requirements

Frequency, Hz	: 60.0	**Generators Running in Parallel**	: 1
Duty	: Standby	**Site Altitude, ft(m)**	: 361(152)
Voltage	: 277/480, Series Wye	**Site Temperature, °C**	: 25
Phase	: 3	**Max. Altr Temp Rise, °C**	: 125
Fuel	: Diesel	**Project Voltage Distortion Limit, %**	: 10
Emissions	: EPA, stationary emergency application		

Calculated Individual Generator Set Load Running and Peak Requirements

Running kW	: 264.4	**Max. Step kW**	: 243.1 In Step 2	**Cumulative Step kW**	: 272.0
Running kVA	: 326.9	**Max. Step kVA**	: 1105.2 In Step 2	**Cumulative Step kVA**	: 1141.2
Running PF	: 0.81	**Peak kW**	: None	**Cumulative Peak kW**	: None
Running NLL kVA	: 0.0	**Peak kVA**	: None	**Cumulative Peak kVA**	: None
Alternator kW	: 264.42				

Generator Set Configuration

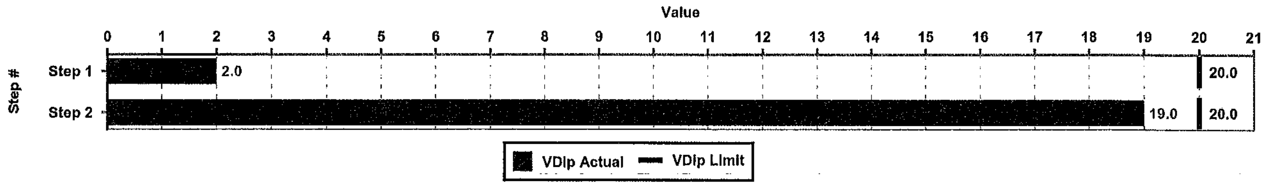
Model	: 450DFEJ*	**Alternator**	: HC5E
Engine Model	: QSX15-G9 Nonroad 2	**Excitation**	: PMG
Fuel	: Diesel		high ambient

Step Level Dips Summary

Step #	Voltage Dip Limit (%)	Expected Step Voltage Dip (%)	Voltage Recovery Time (s) **	Frequency Dip Limit (%)	Expected Frequency Dip (%)	Frequency recovery Time (s) **
1	20	2	0.1	10	1	0.2
2	20	19	0.9	10	4	1.2

Note: Please refer to the model Spec. sheet for bandwidths used to report recovery times. For products manufactured in the United Kingdom it may be assumed that recovery times are based on ISO8528-5 G2 class bandwidths. Voltage and frequency recovery times are estimates. Typically, allow five to ten seconds between application of load steps when designing your system.

**Please note that in some cases the voltage and frequency recovery time estimates are not shown in list. This is a result of "dummy" data points temporarily being used to fill data gaps in the GenSize database. Please disregard these blank results.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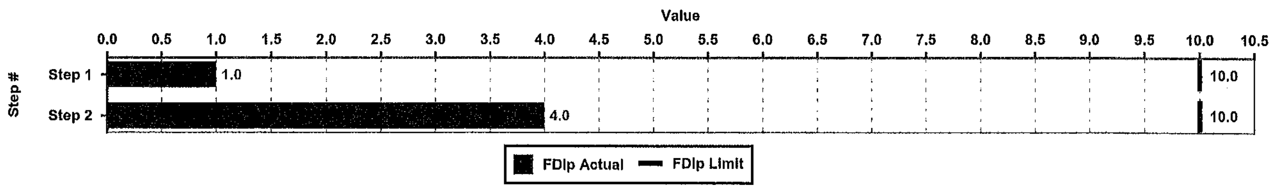
Step #
Step 1
Step 2
2.0
19.0
20.0
20.0
VDip Actual
VDip Limit


Value
Step #
Step 1
Step 2
1.0
4.0
10.0
10.0
FDip Actual
FDip Limit

Attachment 3 – Generator Sizing Information (35% Voltage Dip)

Power Generation

Recommended Generator Report - 300DQDAC

Project - Auburn Well_4

Comments - Based on field notes during startup.

Project Requirements

Frequency, Hz	: 60.0	**Generators Running in Parallel**	: 1
Duty	: Standby	**Site Altitude, ft(m)**	: 361(152)
Voltage	: 277/480, Series Wye	**Site Temperature, °C**	: 25
Phase	: 3	**Max. Altr Temp Rise, °C**	: 125
Fuel	: Diesel	**Project Voltage Distortion Limit, %**	: 10
Emissions	: EPA, stationary emergency application		

Calculated Individual Generator Set Load Running and Peak Requirements

Running kW	: 264.4	**Max. Step kW**	: 243.1 In Step 2	**Cumulative Step kW**	: 272.0
Running kVA	: 326.9	**Max. Step kVA**	: 1105.2 In Step 2	**Cumulative Step kVA**	: 1141.2
Running PF	: 0.81	**Peak kW**	: None	**Cumulative Peak kW**	: None
Running NLL kVA	: 0.0	**Peak kVA**	: None	**Cumulative Peak kVA**	: None
Alternator kW	: 264.42			**Pct Rated Capacity**	: 88.0

Generator Set Configuration

Alternator	: HCI434E	**Engine**	: QSL9-G7
BCode	: B252	**Fuel**	: Diesel
Excitation	: PMG	**Displacement, cu in. (Litre)**	: 543.0(8.9)
Voltage Range	: BR 208-240/416-480	**Cylinders**	: 6
Number of Leads	: 12	**Altitude Knee, ft(m)**	: 1800(549)
Reconnectable	: Yes	**Altitude Slope, % per 1000ft(304.8m)**	: 7
Full Single Phase Output	: No	**Temperature Knee, °F(°C)**	: 104(40)
Increased Motor Starting	: No	**Temperature Slope, % per 18°F(10.0°C)**	: 12
Extended Stack	: No	**Emissions**	: EPA Tier 3
		Cooling Package	: high ambient

Set Performance		Load Requirements	
Running At	: 88.0% Rated Capacity		
Max. Step Voltage Dip, %	: 32	**Max. Allowed Step Voltage Dip**	: 35 In Step 2
Max. Step Frequency Dip, %	: 10	**Max. Allowed Step Frequency Dip**	: 10 In Step 2
Peak Voltage Dip, %	:	**Peak Voltage Dip Limit %**	: 35.0
Peak Frequency Dip, %	:	**Peak Frequency Dip Limit %**	: 10
Site Rated Standby kW/kVA	: 300 / 375	**Running kW**	: 264.4
		Running kVA	: 326.9
Site Rated Max. SkW	: 322	**Effective Step kW**	: 227.5
Max. SkVA	: 1210	**Effective Step kVA**	: 924.4
Temp Rise at Full Load, °C	: 125	**Percent Non-Linear Load**	: 0.0
Voltage Distortion	:	**Voltage Distortion Limit**	: 10
Site Rated Max Step kW Limit	:	**Max Step kW**	:

*Note: Higher temperature rise at full rated load.

*Note: All generator set power derates are based on open generator sets.

Cummins® Power Generation

Steps and Dips Details Report

Project - Auburn Well_4

Project Requirements

Frequency, Hz	: 60.0	**Generators Running in Parallel**	: 1
Duty	: Standby	**Site Altitude, ft(m)**	: 361(152)
Voltage	: 277/480, Series Wye	**Site Temperature, °C**	: 25
Phase	: 3	**Max. Altr Temp Rise, °C**	: 125
Fuel	: Diesel	**Project Voltage Distortion Limit, %**	: 10
Emissions	: EPA, stationary emergency application		

Calculated Individual Generator Set Load Running and Peak Requirements

Running kW	: 264.4	**Max. Step kW**	: 243.1 In Step 2	**Cumulative Step kW**	: 272.0
Running kVA	: 326.9	**Max. Step kVA**	: 1105.2 In Step 2	**Cumulative Step kVA**	: 1141.2
Running PF	: 0.81	**Peak kW**	: None	**Cumulative Peak kW**	: None
Running NLL kVA	: 0.0	**Peak kVA**	: None	**Cumulative Peak kVA**	: None
Alternator kW	: 264.42				

Generator Set Configuration

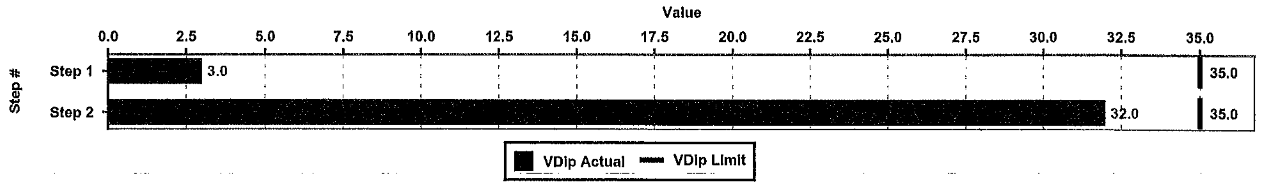
Model	: 300DQDAC	**Alternator**	: HCI434E
Engine Model	: QSL9-G7	**Excitation**	: PMG
Fuel	: Diesel		high ambient

Step Level Dips Summary

Step #	Voltage Dip Limit (%)	Expected Step Voltage Dip (%)	Voltage Recovery Time (s) **	Frequency Dip Limit (%)	Expected Frequency Dip (%)	Frequency recovery Time (s) **
1	35	3	0.2	10	2	0.3
2	35	32	1.5	10	10	2.0

Note: Please refer to the model Spec. sheet for bandwidths used to report recovery times. For products manufactured in the United Kingdom it may be assumed that recovery times are based on ISO8528-5 G2 class bandwidths. Voltage and frequency recovery times are estimates. Typically, allow five to ten seconds between application of load steps when designing your system.

**Please note that in some cases the voltage and frequency recovery time estimates are not shown in list. This is a result of "dummy" data points temporarily being used to fill data gaps in the GenSize database. Please disregard these blank results.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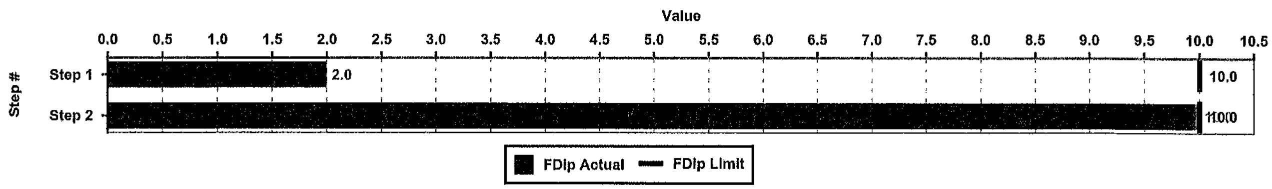
Step #
Step 1
Step 2
3.0
32.0
35.0
VDip Actual
VDip Limit


Value
Step #
Step 1
Step 2
2.0
10.0
FDip Actual
FDip Limit